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APPENDIX

A. TWO ZONE HEAT RELEASE MODEL

The charge mass m is assumed to be divided into an unburned mixture part consisted of fuel, air **and** residual gas, and a burned gas part. The burned gas, of mass fraction x , is assumed to be in thermodynamic equilibrium at temperatures above 1760° K and to be frozen at 1760° K for lower temperatures. The residual gas composition is assumed to be that of the burned gas frozen at 1760° K.

Integrating the unsteady energy equation as applied to the charge from a reference point $*$ where there is negligible heat release, to crank angle θ , the energy equation becomes:

$$[m(1-x)e_u + mx e_b] - m e_u^* = \int_{\theta^*}^{\theta} -(\dot{Q}_L + p \frac{dV}{d\theta}) d\theta \quad (A1)$$

Here, the subscripts u and b refer to the unburned and burned part of the charge and e is the specific internal energy (including the energy of formation). The charge specific internal energy is e_u^* at θ^* , at which the charge consists of unburned mixture only. The other symbols are defined in the nomenclature section.

The heat transfer rate (per crank angle), \dot{Q}_L , is calculated by the Woschni correlation with the burned gas temperature computed from the burned gas specific energy e_b . The burned gas fraction at crank angle θ may then be solved from Eq. (A1).

$$x = \frac{\frac{1}{m} \int_{\theta^*}^{\theta} (\dot{Q}_L + p \frac{dV}{d\theta}) d\theta + (e_u - e_u^*)}{(e_u - e_b)} \quad (A2)$$

The unburned gas temperature T_u , which is needed for the evaluation of e_u , is evaluated by assuming the unburned gas is isentropically compressed by the prevailing pressure. The burned gas temperature T_b is governed by the volume constraint equation:

$$V = \frac{m}{p} [(1-x)R_u T_u + x R_b T_b] \quad (A3)$$

Since e_b is only a function of T_b and composition, Equations (A2) and (A3) may be solved simultaneously for the unknowns x and T_b . Then the cumulative gross heat release from crank angle θ^* to θ is computed by evaluating the Left Hand Side of Eq. (A1).